
Chapter 7 Accelerator Radiation Protection Program Elements

I. Introduction

This chapter summarizes, in outline form, the author's view of the elements needed for a radiation protection program to succeed at an accelerator facility and also gives a short synopsis of some of the important "regulatory" considerations.

II. Accelerator radiation protection program elements

A Establishment of technical design and siting criteria to address radiation protection concerns

1. off-site dose considerations:

- direct radiation
- skyshine
- air activation
- water activation
- groundwater/hydrogeology
- storage and transportation considerations
- radiation buffer zones

2. regulatory considerations

- state/local regulations on groundwater protection
- state/local regulations and requirements for radiation sources
- environmental permits for radiological emissions
- environmental permits for discharges
- environmental monitoring requirements

B. Quantification of radiation source terms

1. primary source terms

- particle type (protons, heavy ions, electrons)
- beam power
- beam energy
- utilization factors

2. secondary radiation sources

- hadrons-through shielding, secondary beams
- electrons-primary beams at electron beams, secondary beams elsewhere
- photons-from electron beams and activated components
- muons (at high energies)

3. incidental radiation sources

- RF sources (e.g., klystrons, RF cavities)
- electrostatic septa
- radiography devices
- calibration sources

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C. Specification of shielding design criteria

- usually some fraction of regulatory limits
- must consider "worst case" (so-called "accident") conditions
- must address normal losses of beam
- should consider dose to personnel maintaining the accelerator
- calculations should be verified by measurement to extent possible

D. Provision for accelerator access control-interlocks and warning devices

Such systems are of paramount importance. Accidental exposure to the accelerated beam can be the most significant radiation hazard, especially at high energies.

1. functional features of the access control system

- emergency off ("scram") switches
- emergency exit provisions
- warning lights/alarms/signs
- search and secure provisions
- "controlled access"
- accommodation to experimental program needs-flexibility
- beam containment devices
- fences, gates, and locks
- hierarchy of access precautions based upon potential dose rates
- exclusion areas should be both locked and interlocked

2. design features of the access control system

- use "fail-safe" radiation damage resistant components
 - {area should be rendered safe in the event that a component fails or power is lost}
- "redundancy" is the general rule
 - in circuitry
 - in methods of disabling beam
- protection of cabling and any function switches
 - from damage (including radiation damage)
 - from tampering
- use solid state devices in such systems with "caution"
 - questions about software reliability
 - need for self-checking features (more tricky than simple "loop" circuits with relays)-see Ref. 2
- system must be designed to be tested
 - written testing procedures must be followed
 - all inputs to be tested
 - periodic testing must be done

2. Radiation alarm system

- measure radiation fields in occupied areas and set off alarms/turn off beams if preset limits are exceeded (may be related to the safety envelope)
- long-term logging of radiation levels to provide occupational and environmental radiation "documentation"
- instrumentation should be calibrated and regularly verified to be functional

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visible/audible alarms should be used in some situations

E. Provision for the control of radioactivation and contamination (removable radioactivity)

1. Control of residual activation in beamline enclosures

surveys upon entry after operations
marking/labeling of activated components
checking of personnel and equipment leaving enclosures for
"contamination" ("removable" radioactivity)
entry control/restrictions

2. Control of activated materials outside of beamline enclosures

labeling system
exclusion for areas frequented by the general public/nonradiation workers
exclusion from lunchrooms, etc.
procedures/criteria for checking materials being shipped for radioactivity
work procedures for activities which might generate removable
radioactivity (e.g., welding, grinding, fine wires, dust)
liquids containing tritium (e.g., cooling water, pump oil, etc.)
targets (sometimes made with hazardous materials; e.g. lithium, beryllium)

F. Provision for the proper management of radioactive waste

identification of radioactive waste
characterization of radioactive waste
avoidance of waste types for which disposal is difficult/impossible
waste minimization
proper shipment and disposal

G. Program for the control of radioactive sources

high intensity calibration sources
sources mounted on experimental apparatus
labeling/inventory considerations
periodic wipes
procedures for
issuing sources
monitoring the inventory and proper usage of sources
transporting sources
collecting sources no longer needed

H. Program for meeting transportation requirements for radioactive materials and sources

U. S. Dept. of Transportation regulations (Code of Federal Regulations
Chapter 49-denoted 49 CFR)
procedures for shipments to/from universities and commercial entities
air transport

I. ALARA program

must keep exposures "as low as reasonably achievable"
usually have ALARA committee
review jobs, plan jobs based on estimated exposures
should be embedded in job planning process where radiation exposures are possible
involves job supervision where significant exposures are probable

J. Decontamination and decommissioning program-planning for the demise of the accelerator

documentation of activated components, especially structures, groundwater, and soil
documentation of contaminated components, structures, etc.
accurate drawings of all structures and components associated with the accelerator
documentation of the operational history

K. Development and maintenance of a safety envelope for accelerator operations

the set of physical and administrative conditions that define the bounding conditions for safe operation at an accelerator facility

L. Audit program

must arrange for objective assessments of program performance
DOE requires complete radiation protection assessment every 3 years
audits are needed to establish that requirements are being met

M. Training program

qualification of radiation workers
radiological control technicians
professional radiation protection personnel
training of experimenters
addressing the needs of visitors

N. Configuration control program

maintenance of drawings of shielding and components
prevention of unauthorized removal of protective features

shielding
beam containment devices
interlocked detectors
alarms
beam intensity measurement devices

O. Dosimetry program

must meet designated standards, either National Voluntary Laboratory Accreditation Program (non-DOE) or DOE Laboratory Accreditation Program (DOELAP) (DOE facilities)

dosimeters must be worn, collected on time, read out, and actions must be taken to correct unnecessarily high exposures

dosimetry records must be retained essentially forever

P. Provision for record keeping program

design calculations

dosimetry results

job planning records

log books of accelerator and beamline operation

survey records

release of radioactive material into the environment

prompt environmental radiation exposures

access control system test results

decontamination and decommissioning program

all written procedures

training records

configuration control program

ALARA analysis

III. Summary of regulatory requirements

In the United States the regulation of the manufacture, distribution and operation of particle accelerators in a manner that does not jeopardize public health and safety is a complex matter shared by several government agencies.

- A. International and national advisory bodies have a role chiefly in developing standards and recommendations applicable to general radiation protection (not specific to accelerators) for adoption by individual nations. These standards include:

recommended dose limits and their technical basis in radiobiology and epidemiology
standards on measuring/calculating external exposure
standards on measuring/calculating internal exposure
standards on instrumentation
program recommendations

These bodies are:

1. The *International Atomic Energy Agency (IAEA)*-In addition to regulatory advice, IAEA has issued three reports on radiation safety at electron linacs, neutron generators, and proton accelerators.
2. The *International Commission on Radiological Protection (ICRP)* -In addition to regulatory advice, ICRP has issued Publication 51 which contains particle fluence to dose equivalent conversion coefficients that are most useful at accelerators.
3. The *International Commission on Radiation Units and Measurements (ICRU)*-In addition to regulatory advice, ICRP has issued Report 28, "Basis Aspects of High-Energy Particle Interactions and Radiation Dosimetry" which presents a good summary of the subject.
4. The *National Council on Radiation Protection and Measurements (NCRP)* -independently chartered by the U. S. Congress. This body has issued a number of reports of interest in accelerator radiation protection.
5. The *American National Standards Institute (ANSI)* -has standards on instrument calibration requirements
6. The *American Society for Testing Materials (ASTM)* - has some standards of interest on performance of materials.
7. The *Institute of Electrical and electronic Engineers (IEEE)* - hosts symposia on instrumentation and issues publications of great utility (nuclear science section).

8. Professional organizations promote this field:

The Health Physics Society
The American Academy of Health Physics
The American Association of Physicist in Medicine

- B. Promulgation of Regulations in the United States pertinent to radiation protection programs at particle accelerators

1. **U. S. Environmental Protection Agency (USEPA)** has responsibility for developing guidance on radiological protection for all Federal agencies- usually, but not always, based on ICRP and NCRP recommendations. Promulgation requires presidential approval. The last modifications were approved by President Reagan. "Ancestors" to this system date back to the Eisenhower administration.

USEPA also has considerable direct regulatory authority with enforcement authority which affects accelerators (which may be delegated to the state "environmental" organizations):

- a. EPA has issued regulations (40 CFR) on airborne radioactivity emissions (Clean Air Act) from DOE-owned facilities (10 mrem/year dose equivalent to offsite personnel).
 - b. EPA has issued regulations (40 CFR) on concentrations of radioactivity in drinking water used by community water systems (Safe Drinking Water Act).
2. The **U. S. Department of Transportation (DOT)** issues regulations on transportation of shipments of radioactive materials (49 CFR). In some states these regulations are enforced by state police forces.
3. **U. S. Department of Energy** has regulatory authority over the accelerators it owns and exercises some authority over institutions to which it issues grants.
- a. has issued, and continues to issue many "Orders" on radiological protection, noteworthy are:

5480.11-"Radiation Protection for Occupational Workers"

sets dose limit of 5 rem per year to occupational workers
sets dose limit of 100 mrem per year to members of the public
requires notification of off-site dose > 10 mrem/year
many other program requirements

This Order is largely replaced, effectively, in Regulation 10 CFR 835 which became effective in December 1993.

5400.5- "Radiation Protection of the Public and the Environment"

sets environmental release limits
institutes USEPA requirements
sets forth environmental monitoring program

This Order will be largely replaced by Regulation 10 CFR 834, when the latter is issued.

Many other orders on virtually every facet of radiation protection program

5480.25- "Safety of Accelerator Facilities" has been issued. This Order extensively regulates the entirety of safety at DOE-owned accelerators.

DOE Notice N 5480.6 "DOE Radiological Control Manual" places stringent requirements on all radiological control programs at DOE facilities.

- b. As of this writing, May 1995, the Department of Energy was extensively reevaluating its directive system so that many changes can be expected in the near term future.

- 3. 36 **states** have regulations concerning accelerators (may or may not apply to federally owned accelerators)

uniformity is encouraged by the Conference of Radiation Control Program Directors which has issued recommendations

often the requirements are patterned after U. S. Nuclear Regulatory Requirements (USNRC) specified in 10 CFR

usually state regulations are incorporated into other state programs for controls of radioactive materials in accord with "agreement state" licensing status with USNRC (USNRC does not explicitly regulate accelerators)

- 4. Some **local** governments (cities, counties) etc., may have additional requirements. New York City is a well-known example.

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